



Searches for a high mass Standard Model Higgs boson at the Tevatron

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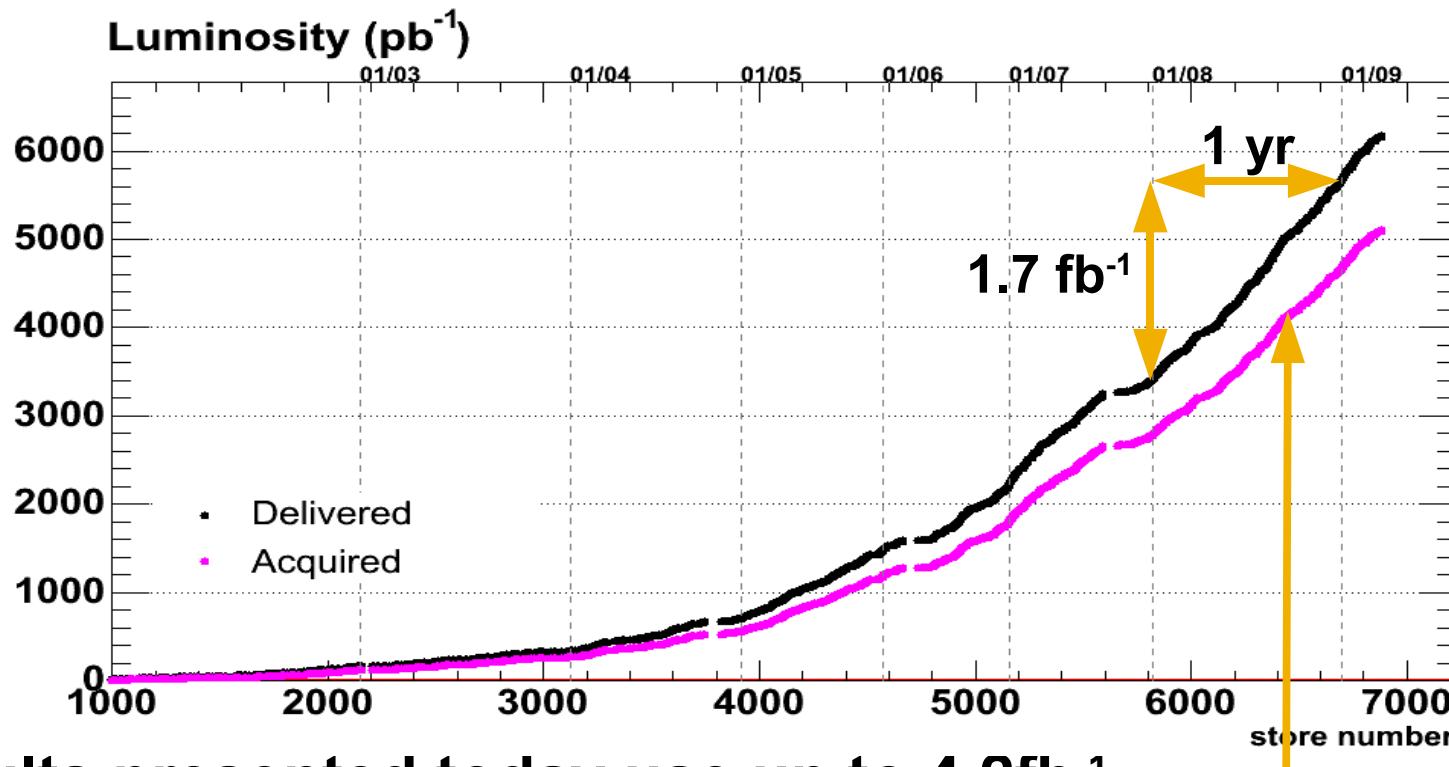
On behalf of the CDF and D0 Collaborations

Moriond QCD, La Thuile, Italy

March 14-21, 2009

CDF and D0 @ Tevatron collider

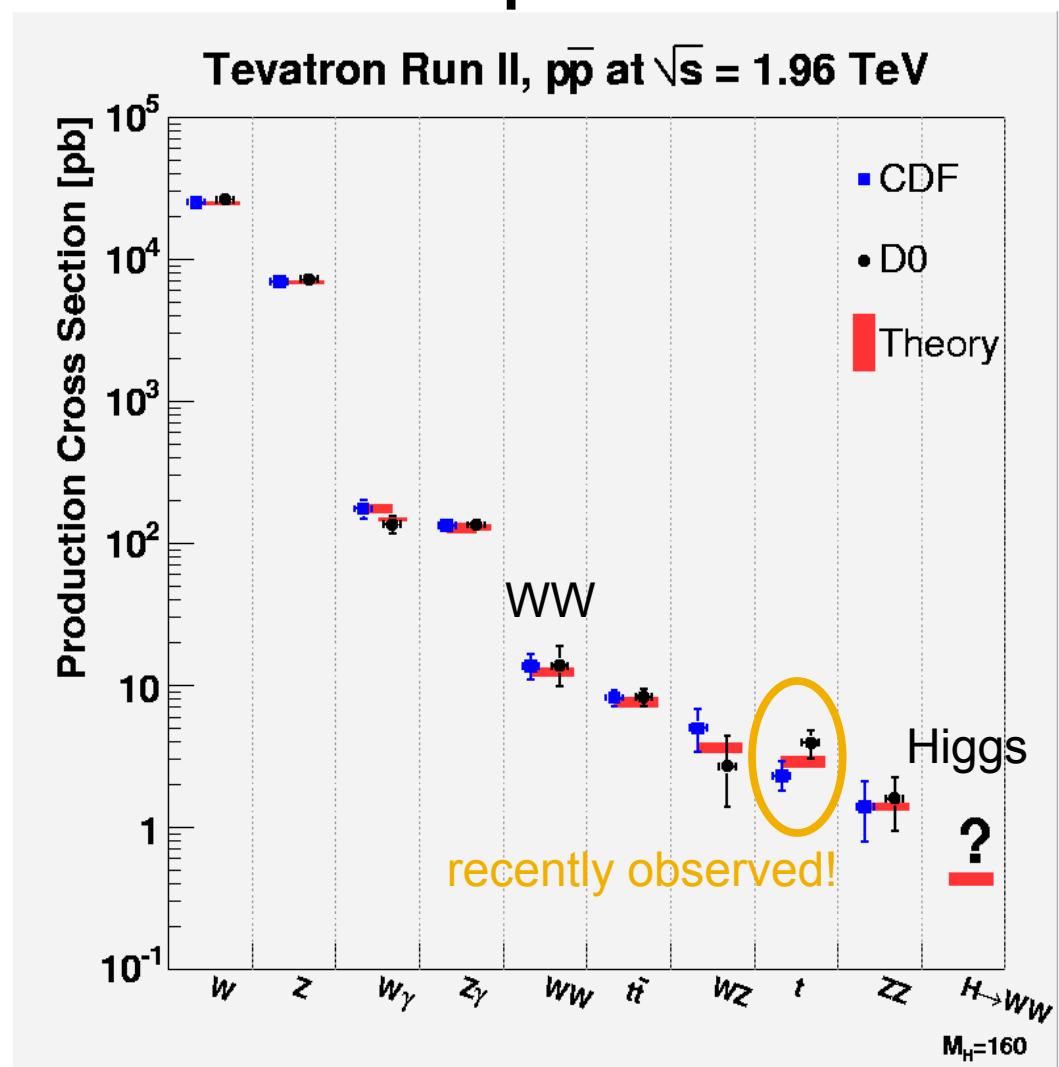
- Tevatron: $p\bar{p}$ collider at $\sqrt{s} = 1.96 \text{ TeV}$, performing really well



- Results presented today use up to 4.2 fb^{-1}
 - Both experiments have about 5 fb^{-1} already on tape
- CDF and D0 detectors, see Thomas Gadfort's talk

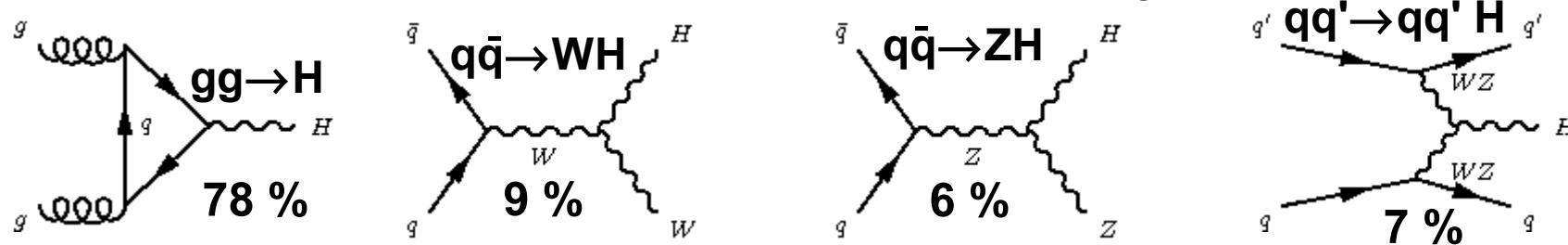
Physics at Tevatron

- Hadron colliders probe Standard Model predictions in several sectors
- Many discoveries
 - $t\bar{t}$, WZ, ZZ, single top
- Now reached sub-pb x-section sensitivity!
- Ready to look for Higgs boson and many other rare processes

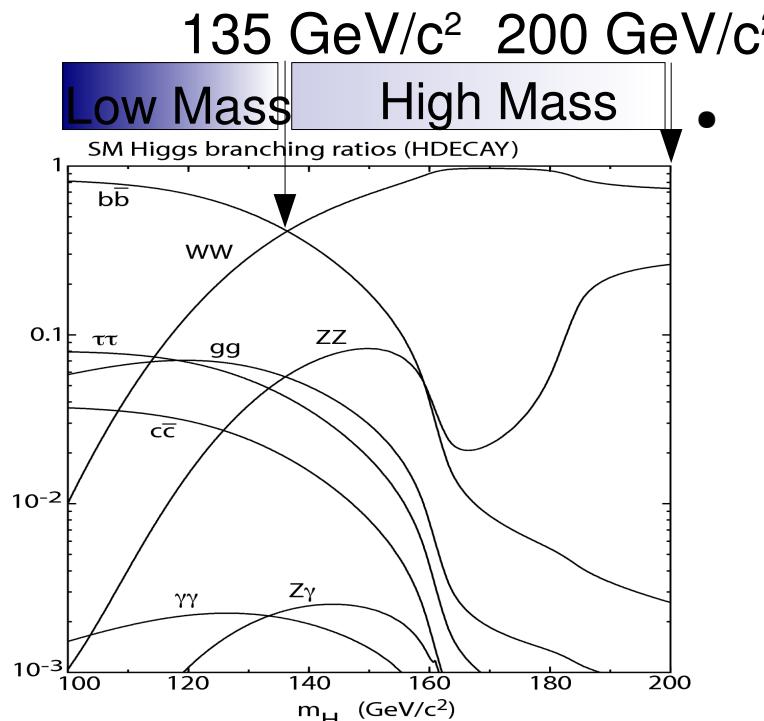


Higgs production and decay at Tevatron

- Four main production mechanisms: $\sigma_{\text{SM}}^{\text{m}(H)=160 \text{ GeV}} \sim 0.6 \text{ pb}$



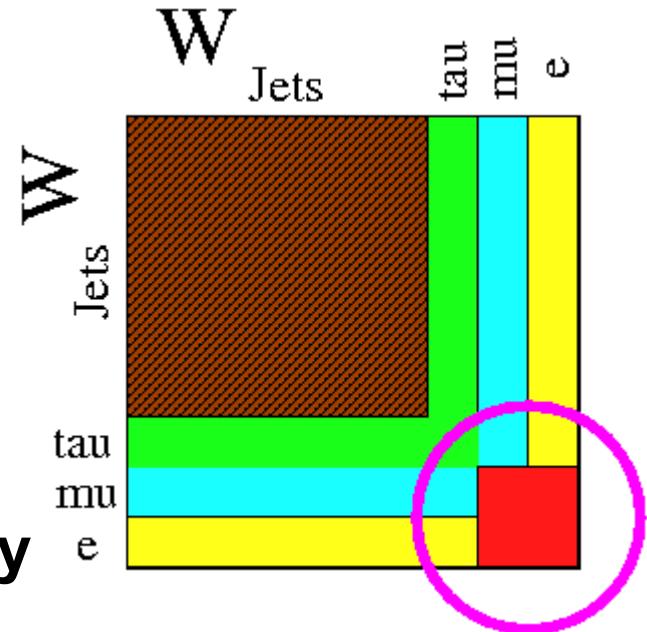
- As sensitivity increases all of them become important !



- For $m_H > 135 \text{ GeV}/c^2$ $H \rightarrow WW$ dominant
 - This is how we define high mass higgs searches at Tevatron
 - $H \rightarrow ZZ$ starts also to be important for $m_H > 180 \text{ GeV}/c^2$

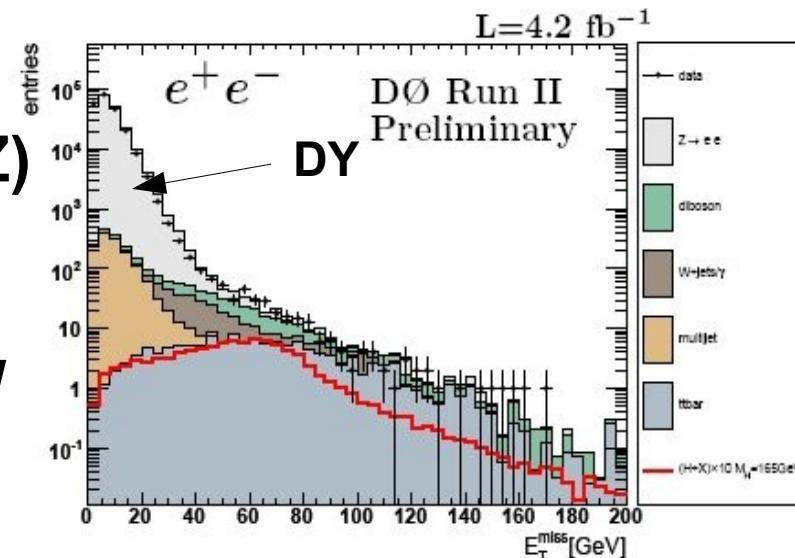
H \rightarrow WW final states

- **W decays**
 - BR(W \rightarrow l v) \sim 32%
 - BR(W \rightarrow hadrons) \sim 68%
- **Hadronic modes have large QCD background: not used.**
- **We select both W decaying leptonically**
 - Easy and clean triggers on single electron or muon
 - Manageable trigger cross section at hadronic colliders
 - Clean signature, exploiting good tracking and muon systems of CDF and D0 detectors
 - Partially includes $\tau \rightarrow (e, \mu)$
 - Overall BR for WW pair to di-lepton (e or μ) \sim 6%



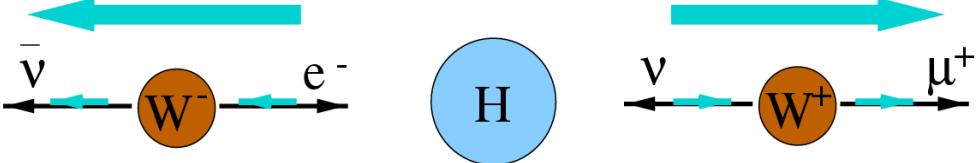
Physics Backgrounds

- Main background contribution comes from $Z/\gamma \rightarrow ll$ events
 - Tends to have low Missing E_T
- Di-boson production (WW,WZ,ZZ)
- $t\bar{t}$ and single top
- $W\gamma$, $W + \text{jets}$ – where the photon/jet is misidentified as a lepton
- Background modeling
 - Data-driven modeling whenever possible: $W+\text{jets}$
 - Most processes modeled with Pythia \otimes Geant3 Monte Carlo
 - Exception is WW: MC@NLO(CDF), Sherpa(D0)
 - Cross sections normalized to (N)NLO calculation



Event selection

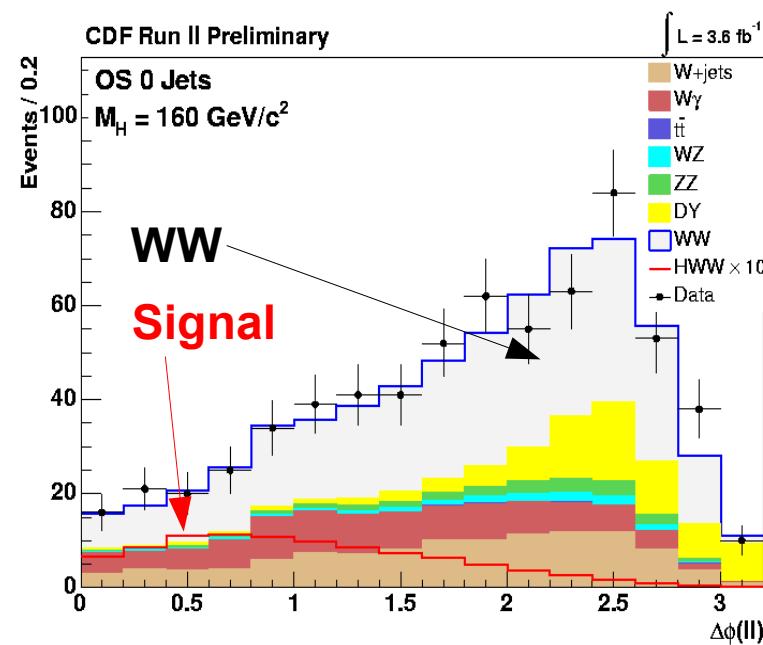
- **Require two opposite sign, isolated electrons or muons**
 - $p_T > 20$ (10) GeV/c for 1st (2nd) lepton at CDF
 - $p_T > 15$ (10) GeV/c for both electrons (muons) at D0
- **Require significant Missing E_T**
- **Spin 1 particles (WW pair) from spin-0 Higgs boson:**



Spin correlation:

Leptons go in the same direction

- **$m(l\bar{l}) > 16$ (CDF), 15 (D0) GeV/c² to reject heavy flavor decays**



Dilepton opening angle
strongest background
discriminant

Analysis strategy

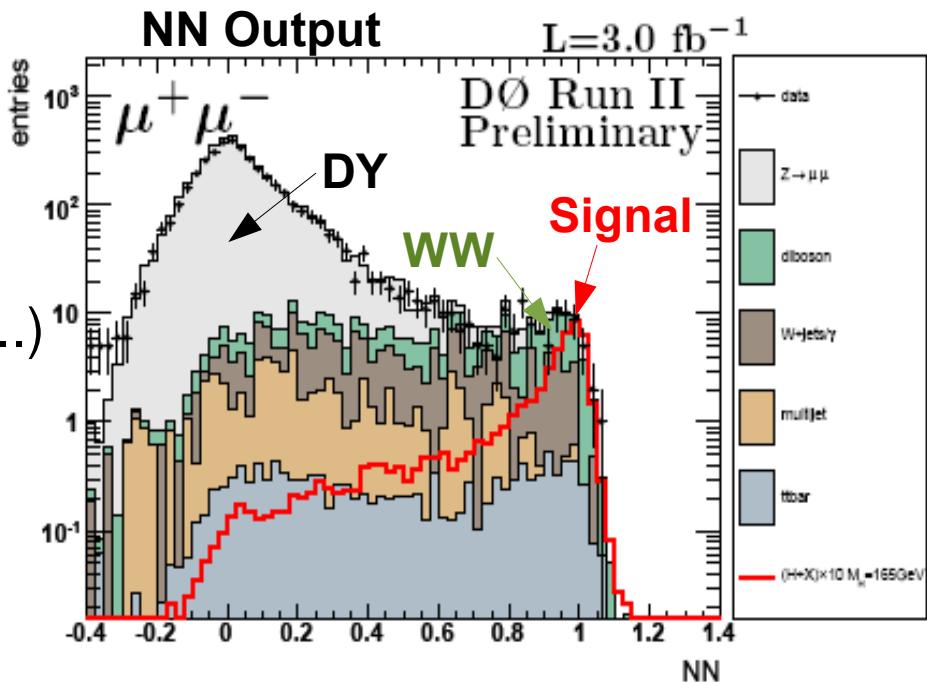
Tevatron Preliminary $\int \mathcal{L} = 3.6 - 4.2 \text{ fb}^{-1}$, $M_H = 160 \text{ GeV}$

	$\mathcal{L} (\text{fb}^{-1})$	Signal	Background	S/\sqrt{B}	Data
CDF	3.6	20.0 ± 2.5	1088 ± 105	0.61	1085
D0 (stat. only)	3.0-4.2	23.2 ± 0.1	4994 ± 30	0.33	4749

- A “simple” counting experiment is not enough...
- Both experiments divide analyses in different channels
 - D0 by di-lepton flavor: ee, e μ , $\mu\mu$
 - CDF by jet ($E_T > 15 \text{ GeV}$) multiplicity: 0, 1, 2+
- Use multivariate techniques (Neural Networks) to improve separation between signal and background
 - one NN for each channel and for each higgs mass hypothesis to probe

- **NN inputs include variables**

- Lepton-specific ($p_T(l)$, ...)
- Kinematics ($H_T = \sum_i |p_T(jet_i)|$, E_T , ...)
- Angular ($\Delta\phi(l, l)$, $\Delta\phi(l, E_T)$, ...)



- **Main background contributions depend on lepton flavor**

- WW for $e\mu$ events
- Drell-Yan for $ee, \mu\mu$ events, but WW still the most difficult to separate from signal

$$\mathcal{L} = 3.0 - 4.2 \text{ fb}^{-1}, M_H = 160 \text{ GeV}$$

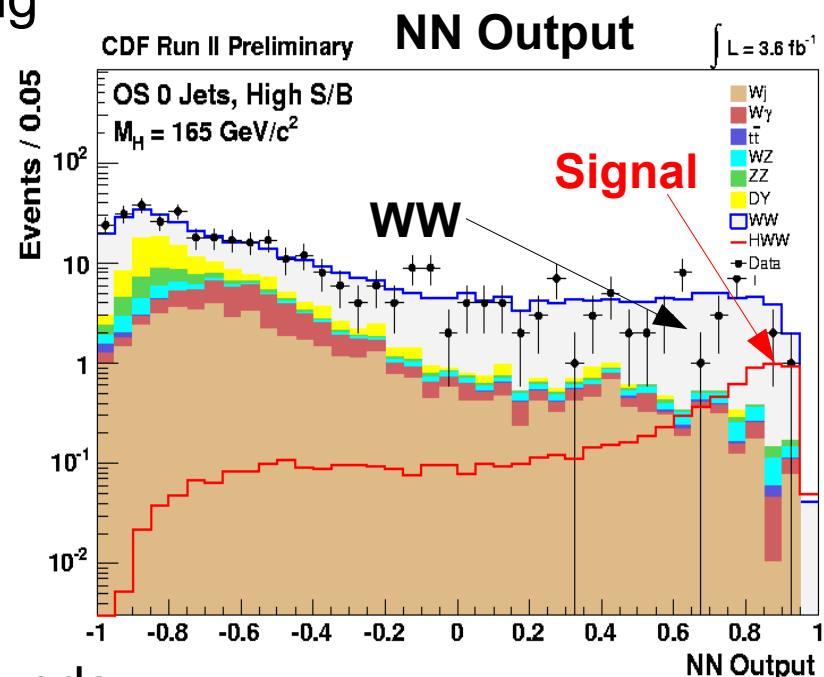
Ch.	$\mathcal{L} (\text{fb}^{-1})$	Signal	Bkgd	Data
$e\mu$	4.2	12.2 ± 0.1	337 ± 10	329
ee	4.2	6.13 ± 0.01	332 ± 15	336
$\mu\mu$	3.0	4.85 ± 0.01	4325 ± 24	4084

- **Neural Networks usage:**

- Input variables analogous to D0
- Variable choice optimized depending on jet multiplicity to exploit different signal/background composition

- **Signal and background composition**

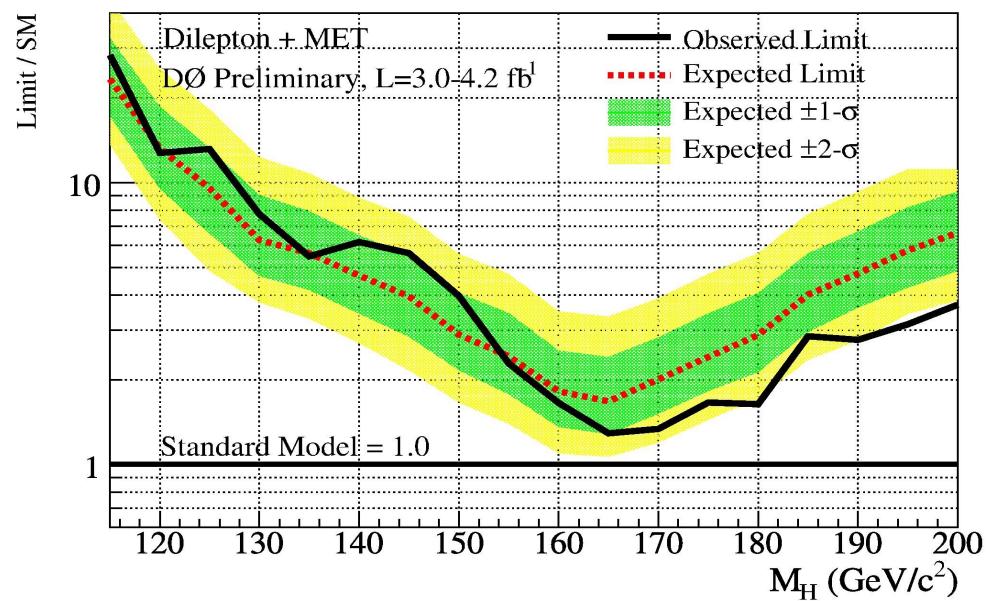
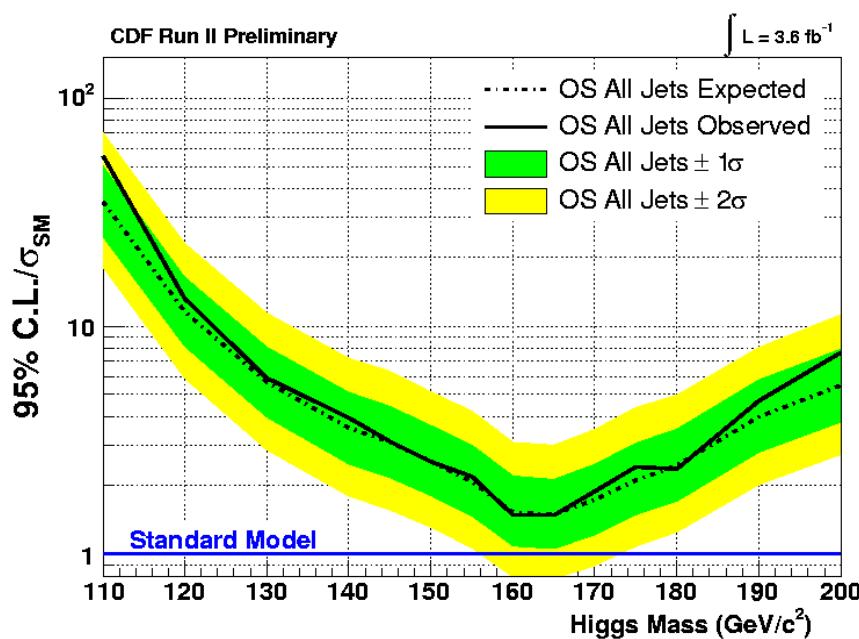
- **0 jets:** signal only $gg \rightarrow H$; main background from WW
- **1 jet:** 22% of the signal from (W/Z)H and Vector Boson Fusion; WW and DY are dominant backgrounds
- **2 or more jets:** 62% of the signal from (W/Z)H and VBF; tt is 68% of the selected sample



$\mathcal{L} = 3.6 \text{ fb}^{-1}, M_H = 160 \text{ GeV}$

Channel	Signal	Bkgd	Data
0 Jets	9.5 ± 1.4	637 ± 67	654
1 Jet	5.98 ± 0.78	278 ± 35	262
2+ Jets	4.53 ± 0.52	173 ± 23	169

- Use NN output distributions to calculate 95% CL upper limits in the $110 < m_H < 200 \text{ GeV}/c^2$ mass range
 - CDF uses a Bayesian method
 - D0 adopts a modified frequentist approach (CL_S)



Both experiments are reaching SM sensitivity

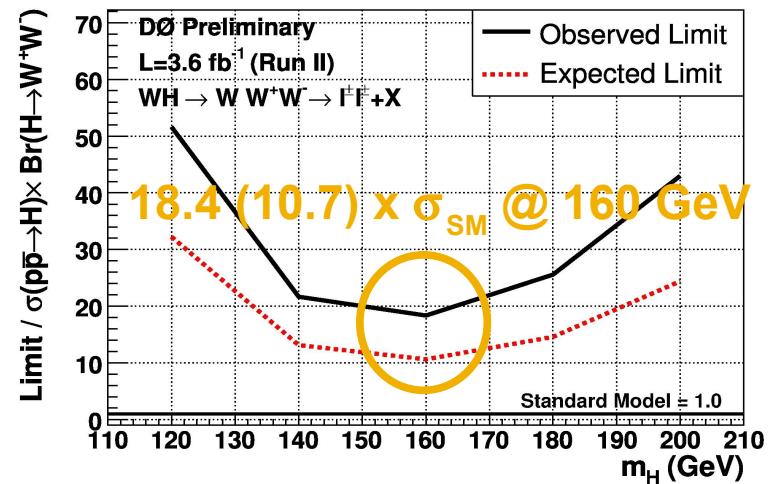
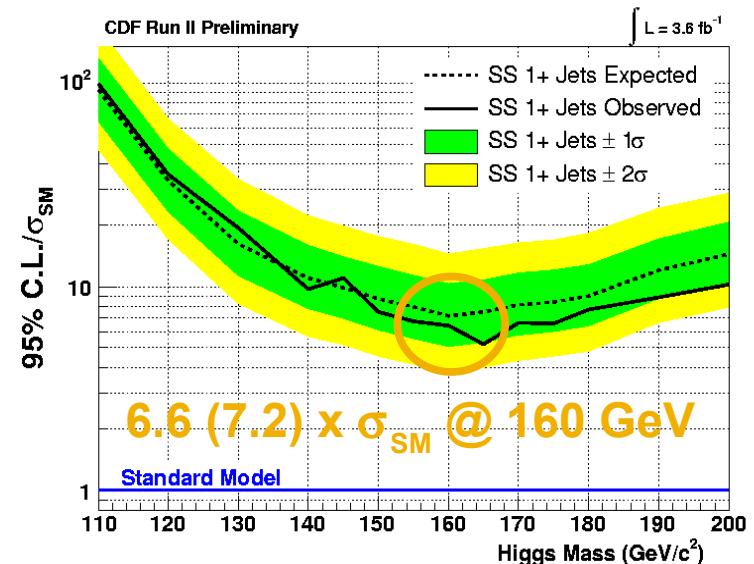
95% CL limits, $M_H = 160 \text{ GeV} (\times \sigma_{SM})$

	Expected	Observed
CDF	1.5	1.5
D0	1.8	1.7

Additional Higgs acceptance

- Select two same-sign leptons events to increase acceptance

- $WH \rightarrow WWW \rightarrow l^\pm l^\pm + X$ is the main signal contribution
- Main Background contributions:
 - Lepton charge misidentification
 - jets faking leptons
- New CDF analysis using 3.6 fb^{-1}
 - analysis technique similar to Opposite Sign analysis
 - Require at least 1 jet
- Very recent D0 analysis uses 3.6 fb^{-1}
 - Likelihood discriminant
 - Not in Tevatron combination

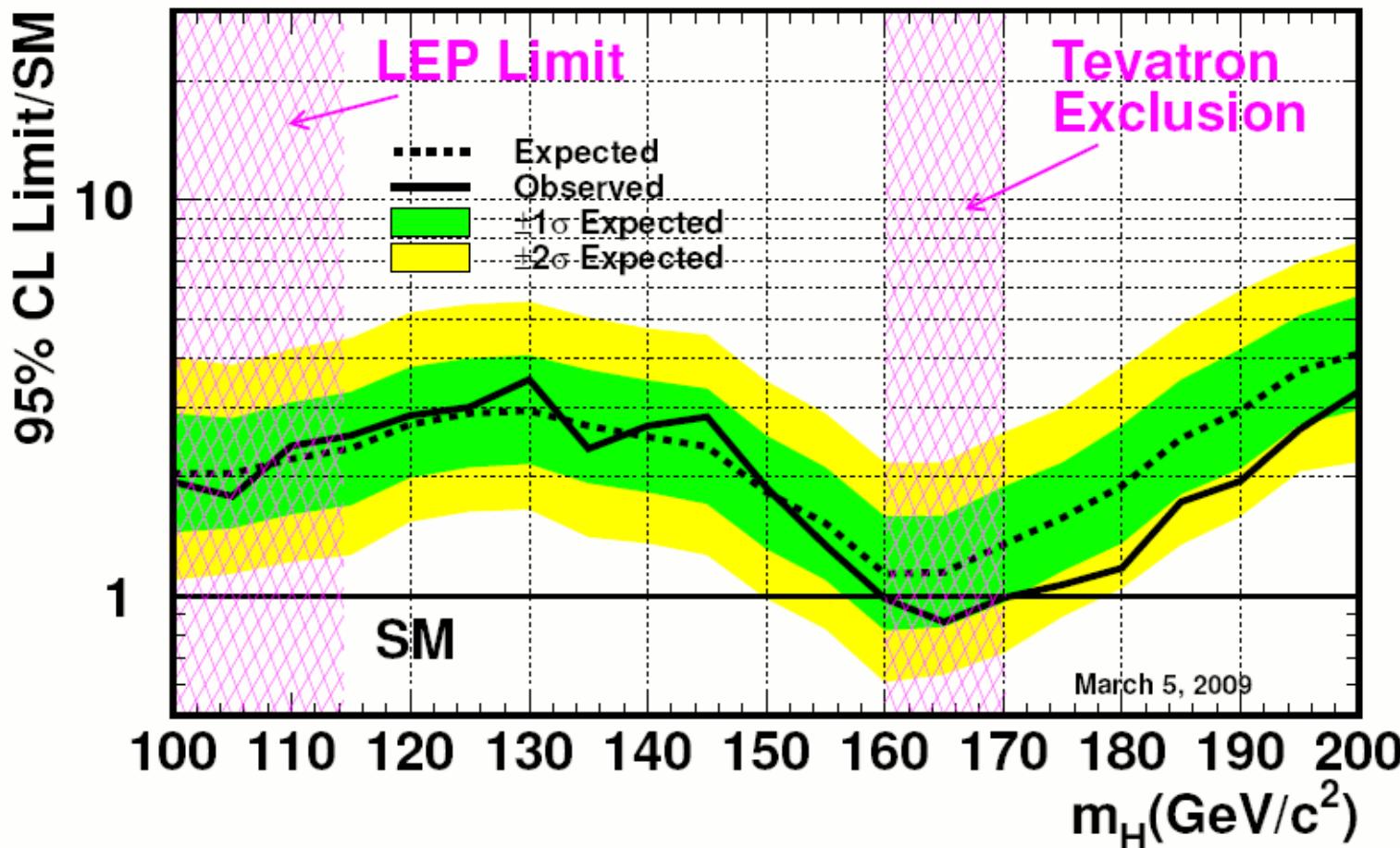


Higgs Tevatron combination

- Both experiments agreed on classifying the systematics uncertainties in two main classes
 - Rate systematics: Dominant. Affects normalization of NN output distribution. Major contributors are theoretical cross section errors.
 - Shape systematics: Small effect on sensitivity. Modify shape of NN output distribution. One example is Jet Energy Scale.
- Use latest signal and background x-sections available
 - In particular, new $gg \rightarrow H$ cross section calculation by Florian *et al.* (arXiv:0901.2427), Anastasiou *et al.* (arXiv:0811.3458), which includes MSTW 2008 pdfs
- CDF and D0 combination
 - It's not just a $\sqrt{2}$ factor: correlate systematics among experiments
 - Using two methods: Bayesian and CL_s methods, similar results

Tevatron Higgs search results

Tevatron Run II Preliminary, $L=0.9\text{-}4.2 \text{ fb}^{-1}$



We exclude an Higgs boson in the $160\text{-}170 \text{ GeV}/c^2$ mass range!!

- Expected limits of 1.1 and $1.4 \times \sigma_{\text{SM}}$ at 160 and $170 \text{ GeV}/c^2$

Fermilab Press Release

http://www.fnal.gov/pub/presspass/press_releases/Higgs-mass-constraints-20090313.html



09-06

March 13, 2009

Friday, March 13th !!

For immediate release

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For additional media contacts of the worldwide InterAction collaboration go to:
<http://www.interactions.org/presscontacts/>

Graphics, photos and videos are available at:

http://www.fnal.gov/pub/presspass/press_releases/Higgs-mass-constraints-20090313-images.html

Fermilab experiments constrain Higgs mass

CDF, DZero experiments exclude significant fraction of Higgs territory

Batavia, Ill.—The territory where the Higgs boson may be found continues to shrink. The latest analysis of data from the CDF and DZero collider experiments at the U.S. Department of Energy's Fermilab now excludes a significant fraction of the

- **Exciting times for Higgs searches at Tevatron**
- **We exclude at 95%CL a Standard Model Higgs boson in the $160 < m_H < 170 \text{ Gev}/c^2$ mass range for the first time!!**
- **Tevatron is making big and fast improvements in (not only high mass) Higgs searches**
 - Rapid incorporation of new data and analysis improvements
 - Still lots of ideas under-going to improve analyses
 - Sensitivity continues to improve faster than luminosity scaling
 - Now sensitivity $< 3 \times \sigma_{\text{SM}}$ for $m_H < 190 \text{ GeV}$!
 - Expect soon exclusion by each experiment alone
 - Expect increase of mass range where Tavatron has SM sensitivity!

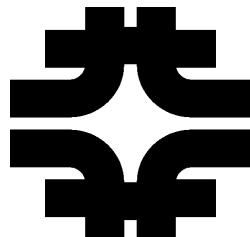
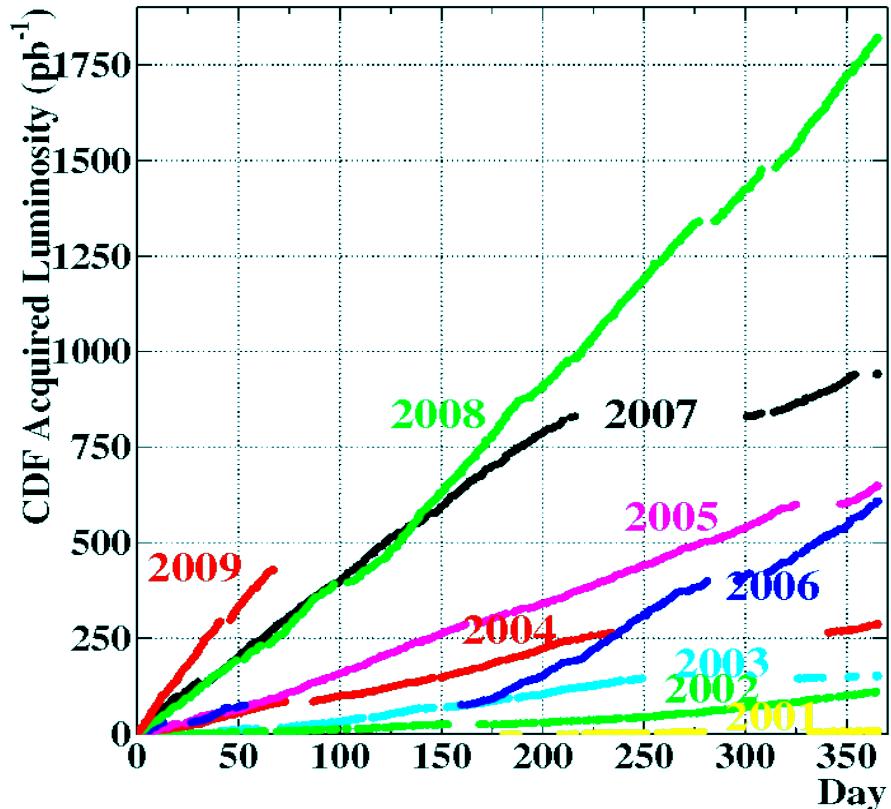
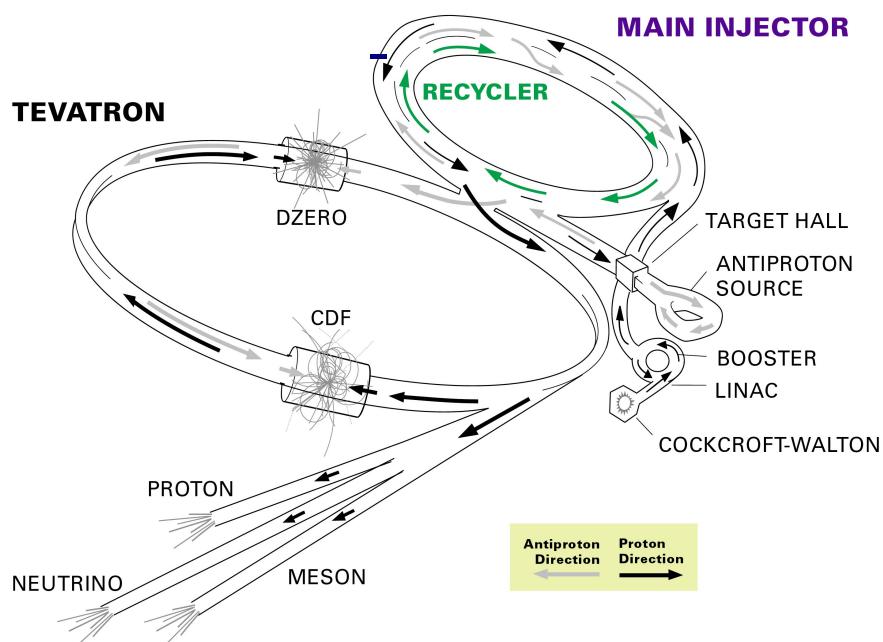
STAY TUNED!!

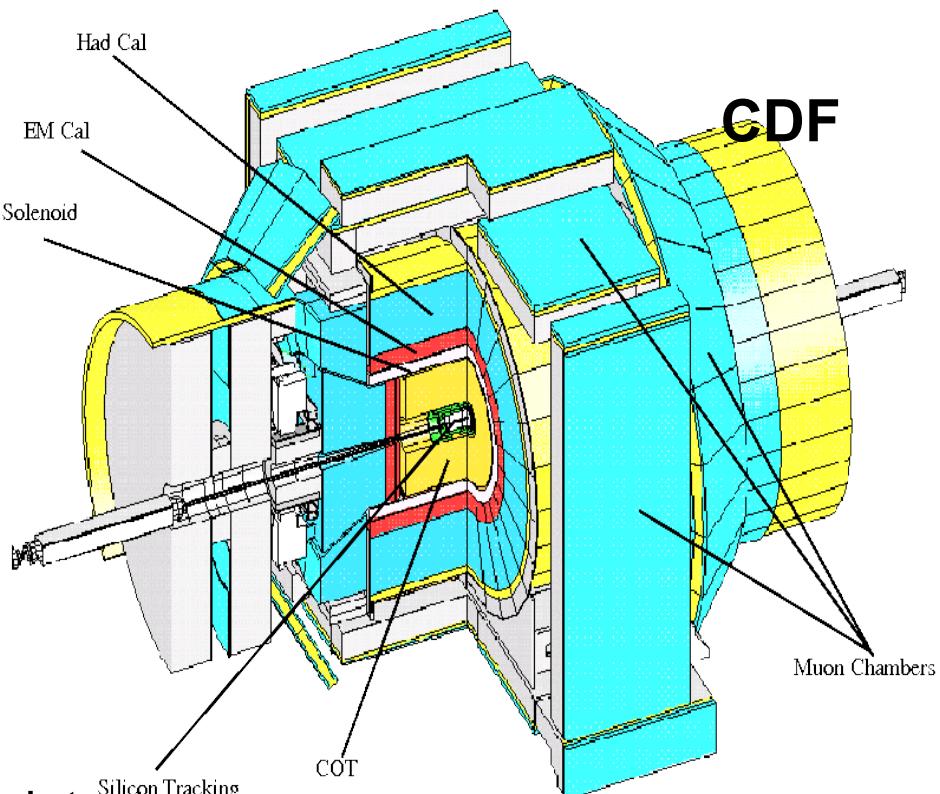
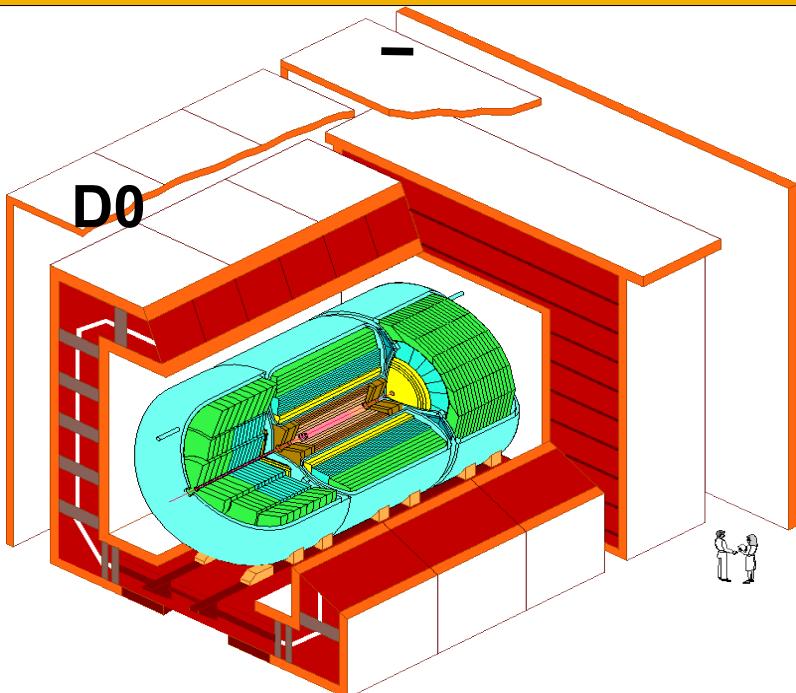
Backup

- **Tevatron, CDF and D0**
- **X-sec table and references**
- **Details for CDF, D0 $H \rightarrow WW$ analyses**
 - Selections
 - Expected yields
 - Systematic tables
 - Matrix Element calculation (CDF)
 - CDF and D0 table of limits
- **Improvements in plots**
- **Combination**
 - Bayesian approach - details
 - CL_s combined limits and full limit tables

Tevatron Performance

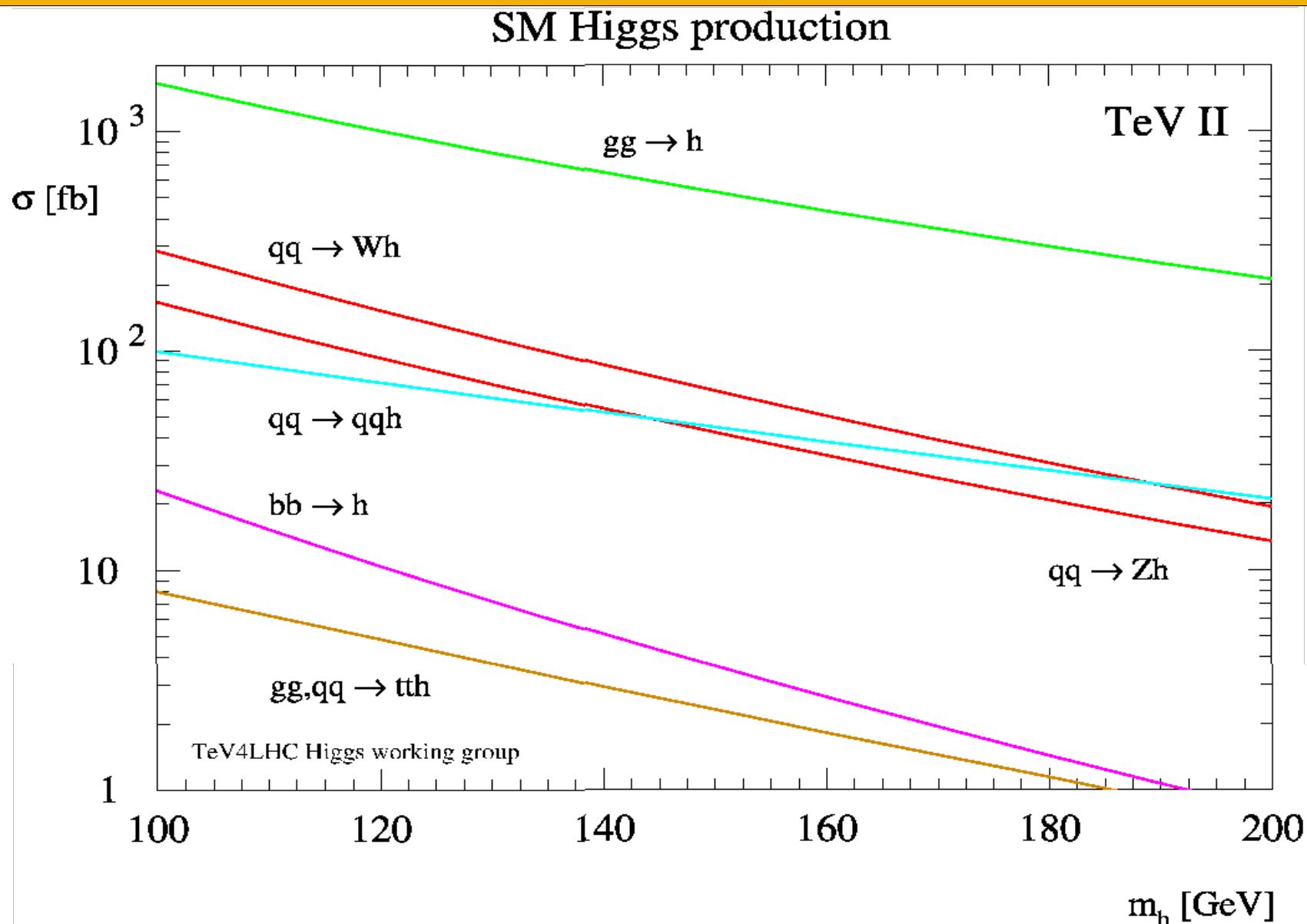
FERMILAB'S ACCELERATOR CHAIN





- Tracking:
 - Silicon detectors
 - drift chamber (CDF) or fiber tracker (D0)
- Calorimeter
- Muon detectors

Higgs Production at the Tevatron



Higgs production x-sections

- **New ggH signal x-sections by Florian at Grazzini
(arXiv:0901.2427), Anastasiou *et al.* (arXiv:0811.3458)**
 - included NNLL $\sigma(gg \rightarrow H)$, latest MSTW2008 pdf, 2-loop ewk corrections, exact b-quark treatment @ NLO

M_H (GeV/c ²)	$\sigma_{gg \rightarrow H}$ (pb)	σ_{WH} (pb)	σ_{ZH} (pb)	σ_{VBF} (pb)	$\text{Br}_{H \rightarrow WW}$
110	1.413	0.208	0.124	0.084	0.044
120	1.093	0.153	0.093	0.072	0.132
130	0.858	0.114	0.071	0.061	0.287
140	0.682	0.086	0.054	0.052	0.483
145	0.611	0.075	0.048	0.048	0.573
150	0.548	0.065	0.042	0.045	0.682
155	0.492	0.057	0.037	0.041	0.801
160	0.439	0.051	0.033	0.038	0.901
165	0.389	0.044	0.029	0.035	0.957
170	0.349	0.039	0.026	0.033	0.965
175	0.314	0.034	0.023	0.031	0.951
180	0.283	0.031	0.021	0.028	0.935
190	0.231	0.024	0.017	0.024	0.776
200	0.192	0.019	0.014	0.021	0.735

D0 analysis: Selections

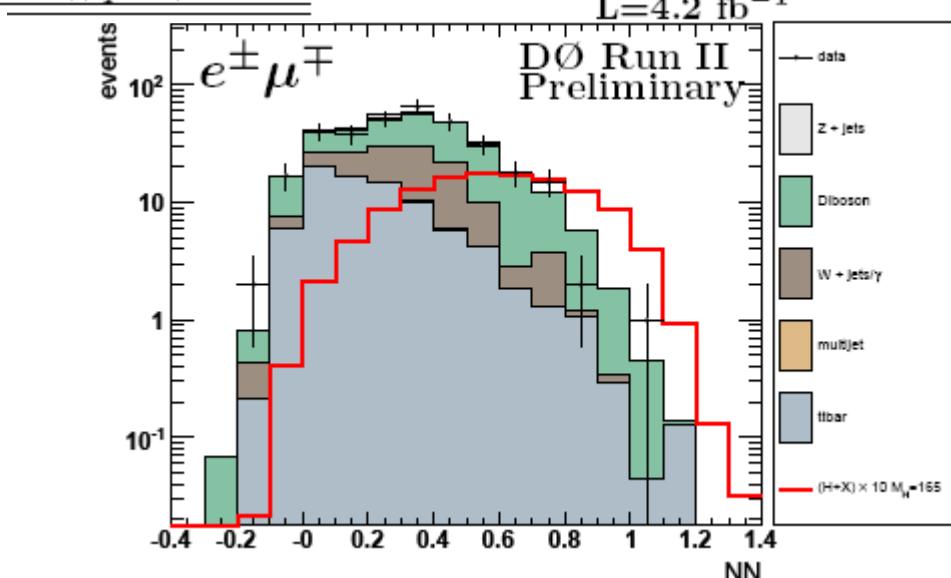
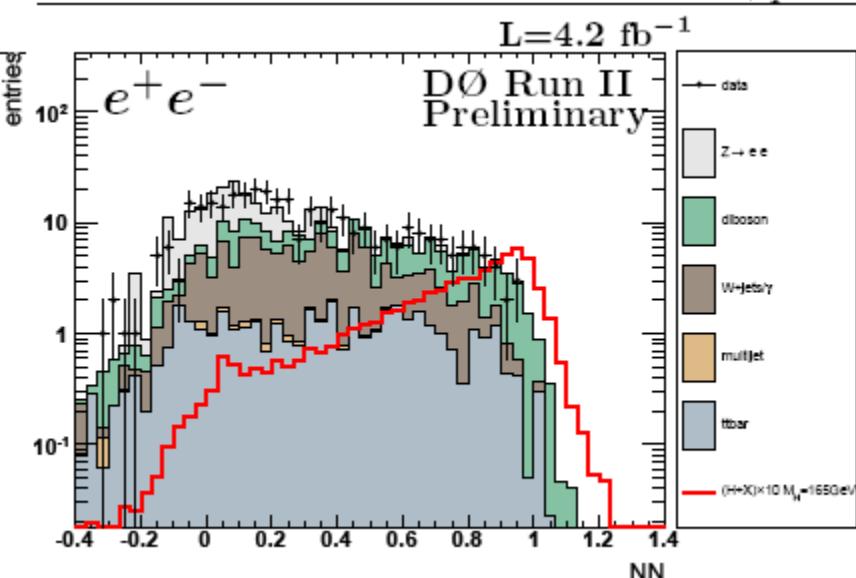
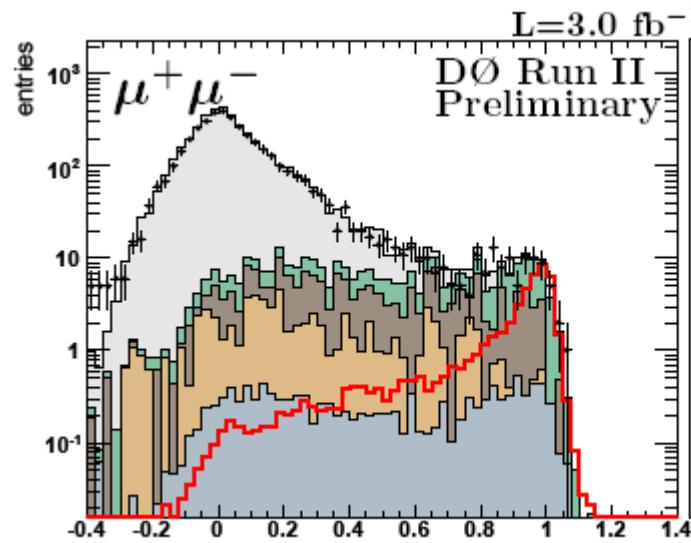
Final state		$e\mu$	ee	$\mu\mu$	
Cut 0	Pre-selection	lepton ID, leptons with opposite charge and $p_T^\mu > 10$ GeV and $p_T^e > 15$ GeV invariant mass $M_{\ell\ell} > 15$ GeV $\mu\mu$: $n_{\text{jet}} < 2$ for $p_T^{\text{jet}} > 15$ GeV, $\Delta R(\mu, \text{jet}) > 0.1$ and $p_T^\mu > 15$ GeV for the leading μ			
Cut 1	Missing Transverse Energy E_T (GeV)	> 20	> 20		
Cut 2	E_T^{Scaled}	> 6	> 6		
Cut 3	$M_T^{\min}(\ell, E_T)$ (GeV)	> 20	> 30		
Cut 4	$p_T^{\mu\mu}$ (GeV) for $n_{\text{jet}} = 0$ E_T (GeV) for $n_{\text{jet}} = 1$			> 20 > 20	
Cut 5	$\Delta\phi(\ell, \ell)$	< 2.0	< 2.0	< 2.5	

	ee pre-selection	ee final	$e\mu$ pre-selection	$e\mu$ final	$\mu\mu$ pre-selection	$\mu\mu$ final
$Z \rightarrow ee$	218695 ± 704	108 ± 14	280.6 ± 3.3	$0.0^{+0.1}_{-0.0}$	—	—
$Z \rightarrow \mu\mu$	—	—	274.6 ± 0.9	5.8 ± 0.1	235670 ± 158	3921 ± 22
$Z \rightarrow \tau\tau$	1135 ± 16	1.4 ± 0.5	3260 ± 3	7.3 ± 0.1	1735 ± 10	66 ± 2
$t\bar{t}$	131.4 ± 1.4	39.9 ± 0.8	272.0 ± 0.3	82.5 ± 0.2	19.93 ± 0.05	12.55 ± 0.04
$W + \text{jets}$	241 ± 5	98 ± 3	183 ± 4	78.6 ± 2.8	214 ± 7	134 ± 5
WW	172.2 ± 2.6	66.8 ± 1.6	421.2 ± 0.1	154.7 ± 0.1	159.0 ± 0.3	92.8 ± 0.3
WZ	112.5 ± 0.2	9.68 ± 0.05	20.5 ± 0.1	6.6 ± 0.1	47.3 ± 0.5	19.4 ± 0.3
ZZ	98.2 ± 0.2	7.68 ± 0.07	5.3 ± 0.1	0.60 ± 0.01	40.5 ± 0.2	15.1 ± 0.1
Multijet	1351 ± 55	$1.7^{+2.0}_{-1.7}$	279 ± 168	$1.1^{+9.6}_{-1.1}$	386 ± 20	64 ± 8
Signal ($M_H = 165$ GeV)	9.45 ± 0.01	6.13 ± 0.01	17.1 ± 0.01	12.2 ± 0.1	5.43 ± 0.01	4.85 ± 0.01
Total Background	221937 ± 707	332 ± 15	4995 ± 168	337 ± 10	238272 ± 159	4325 ± 24
Data	221530	336	4995	329	239923	4084

D0 analysis: NN output

NN Analysis Variables

p_T of leading lepton	$p_T(\ell_1)$
p_T of trailing lepton	$p_T(\ell_2)$
Minimum of both lepton qualities	$\min(q_{\ell 1}, q_{\ell 2})$
Vector sum of the transverse momenta of the leptons:	$p_T(\ell_1) + p_T(\ell_2)$
Scalar sum of the transverse momenta of the jets:	$H_T = \sum_i p_T(\text{jet}_i) $
Invariant mass of both leptons	$M_{\text{inv}}(\ell_1, \ell_2)$
Minimal transverse mass of one lepton and E_T	M_T^{min}
Missing transverse energy	E_T
Scalar transverse energy	E_T^{scalar}
Azimuthal angle between selected leptons	$\Delta\phi(\ell_1, \ell_2)$
Solid angle between selected leptons ($e\mu$ only)	$\Delta\Theta(\ell_1, \ell_2)$
ΔR between selected leptons ($e\mu$ only)	$\Delta R(\ell_1, \ell_2)$
Azimuthal angle between leading lepton and E_T	$\Delta\phi(E_T, \ell_1)$
Azimuthal angle between trailing lepton and E_T	$\Delta\phi(E_T, \ell_2)$



D0 analysis: Systematics

Syst(%)	Signal	Σ Bkg
JES	0.3	1.1
Jet ID	6.0	0.0
PV Rew	0.9	0.6
Z- p_T Rew	4.6	0.
WW NLO	6.8	3.0
σ	5	4
Multijet	0	2
PDF	4	4
Lepton ID	5.7	5.7

- Two classes of systematic:

Shape systematics

- Modify output of discriminant
- Also change normalization

Flat systematics

- Affect only normalization, do not modify shape

CDF analysis: selections

CDF Run II Preliminary $\int \mathcal{L} = 3.6 \text{ fb}^{-1}$

$M_H = 160 \text{ GeV}/c^2$

$t\bar{t}$	1.35	\pm	0.21
DY	80	\pm	18
WW	318	\pm	35
WZ	14	\pm	1.9
ZZ	20.7	\pm	2.8
$W+\text{jets}$	113	\pm	27
$W\gamma$	92	\pm	25
Total Background	637	\pm	67
$gg \rightarrow H$	9.5	\pm	1.4
Total Signal	9.5	\pm	1.4
Data	654		

OS 0 Jets

CDF Run II Preliminary $\int \mathcal{L} = 3.6 \text{ fb}^{-1}$

$M_H = 160 \text{ GeV}/c^2$

$t\bar{t}$	0.11	\pm	0.03
DY	11.99	\pm	3.65
WW	0.020	\pm	0.005
WZ	6.82	\pm	0.93
ZZ	1.44	\pm	0.20
$W+\text{jets}$	22.45	\pm	6.73
$W\gamma$	3.23	\pm	1.00
Total Background	46.07	\pm	8.02
WH	1.19	\pm	0.16
ZH	0.19	\pm	0.02
Total Signal	1.38	\pm	0.18
Data	41		

SS 1+ Jets

CDF Run II Preliminary $\int \mathcal{L} = 3.6 \text{ fb}^{-1}$

$M_H = 160 \text{ GeV}/c^2$

$t\bar{t}$	34.9	\pm	5.5
DY	85	\pm	27
WW	85.3	\pm	9.1
WZ	14.5	\pm	2.0
ZZ	5.48	\pm	0.75
$W+\text{jets}$	40	\pm	10
$W\gamma$	13.2	\pm	4.0
Total Background	278	\pm	35
$gg \rightarrow H$	4.70	\pm	0.72
WH	0.661	\pm	0.086
ZH	0.244	\pm	0.032
VBF	0.381	\pm	0.061
Total Signal	5.98	\pm	0.78
Data	262		

OS 1 Jet

CDF Run II Preliminary $\int \mathcal{L} = 3.6 \text{ fb}^{-1}$

$M_H = 160 \text{ GeV}/c^2$

$t\bar{t}$	100	\pm	17
DY	33	\pm	11
WW	17.6	\pm	4.0
WZ	3.76	\pm	0.52
ZZ	1.62	\pm	0.22
$W+\text{jets}$	14.7	\pm	4.0
$W\gamma$	2.12	\pm	0.70
Total Background	173	\pm	23
$gg \rightarrow H$	1.75	\pm	0.30
WH	1.39	\pm	0.18
ZH	0.693	\pm	0.090
VBF	0.70	\pm	0.11
Total Signal	4.53	\pm	0.52
Data	169		

OS 2+ Jets

CDF Analysis: selections

CDF Run II Preliminary			$\int \mathcal{L} = 3.6 \text{ fb}^{-1}$			CDF Run II Preliminary			$\int \mathcal{L} = 3.6 \text{ fb}^{-1}$		
$M_H = 160 \text{ GeV}/c^2$						$M_H = 160 \text{ GeV}/c^2$					
$t\bar{t}$	136	\pm	23	$t\bar{t}$		136	\pm	23			
DY	198	\pm	37	DY		210	\pm	38			
WW	421	\pm	46	WW		421	\pm	46			
WZ	32.0	\pm	4.4	WZ		38.9	\pm	5.3			
ZZ	27.8	\pm	3.8	ZZ		29.2	\pm	4.0			
$W+\text{jets}$	167	\pm	41	$W+\text{jets}$		189	\pm	48			
$W\gamma$	107	\pm	29	$W\gamma$		110	\pm	29			
Total Background	1.088	\pm	105	Total Background		1134	\pm	110			
$gg \rightarrow H$	15.9	\pm	2.3	$gg \rightarrow H$		15.9	\pm	2.3			
WH	2.05	\pm	0.27	WH		3.24	\pm	0.42			
ZH	0.94	\pm	0.12	ZH		1.13	\pm	0.15			
VBF	1.08	\pm	0.17	VBF		1.08	\pm	0.17			
Total Signal	20.0	\pm	2.5	Total Signal		21.4	\pm	2.5			
Data	1085			Data		1126					

OS All Jets

OS+SS

CDF Analysis: Systematics (1 J)

Uncertainty Source	WW	WZ	ZZ	$t\bar{t}$	DY	$W\gamma$	$W+\text{jet}$
Cross Section							
Scale							
PDF Model							
Total	6.0%	6.0%	6.0%	10.0%	5.0%	10.0%	
Acceptance							
Scale							
PDF Model	1.9%	2.7%	2.7%	2.1%	4.1%	2.2%	
Higher-order Diagrams	5.0%	10.0%	10.0%	10.0%		10.0%	
Jet Modeling	-1.0%				30.0%	15.0%	
Conversion Modeling						20.0%	
Jet Fake Rates							
(Low S/B)							22.2%
(High S/B)							31.5%
MC Run Dependence	1.9%			1.0%		2.4%	
Lepton ID Efficiencies	2.0%	2.0%	2.2%	1.8%	2.0%	2.0%	
Trigger Efficiencies	2.1%	2.1%	2.1%	2.0%	3.4%	7.0%	
Luminosity	5.9%	5.9%	5.9%	5.9%	5.9%	5.9%	

Uncertainty Source	$gg \rightarrow H$	WH	ZH	VBF
Cross Section				
Scale				
PDF Model	5.1%			
Total	12.0%	5.0%	5.0%	10.0%
Acceptance				
Scale (leptons)	2.8%			
Scale (jets)	-5.1%			
PDF Model (leptons)	1.7%	1.2%	0.9%	2.2%
PDF Model (jets)	-1.9%			
EWK Higher-order Diagrams		10.0%	10.0%	10.0%
Lepton ID Efficiencies	1.9%	1.9%	1.9%	1.9%
Trigger Efficiencies	3.3%	2.1%	2.1%	3.3%
Luminosity	5.9%	5.9%	5.9%	5.9%

Matrix Elements at CDF (0J only)

$$P(\vec{x}_{obs}) = \frac{1}{\langle \sigma \rangle} \int \frac{d\sigma_{th}(\vec{y})}{d\vec{y}} \varepsilon(\vec{y}) G(\vec{x}_{obs}, \vec{y}) d\vec{y}$$

\vec{x}_{obs}	Observed leptons and E_T
\vec{y}	True lepton 4-vectors (l, v)
σ_{th}	Leading order theoretical cross-section
$\varepsilon(\vec{y})$	Efficiency & acceptance
$G(\vec{x}_{obs}, \vec{y})$	Resolution effects
$1/\langle \sigma \rangle$	Normalization

CDF models 5 modes:

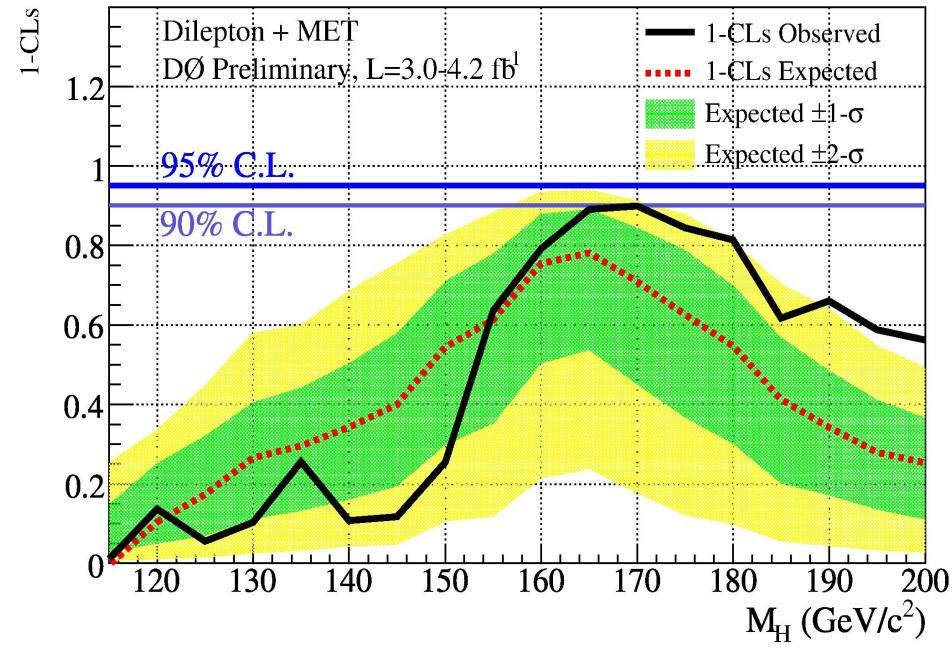
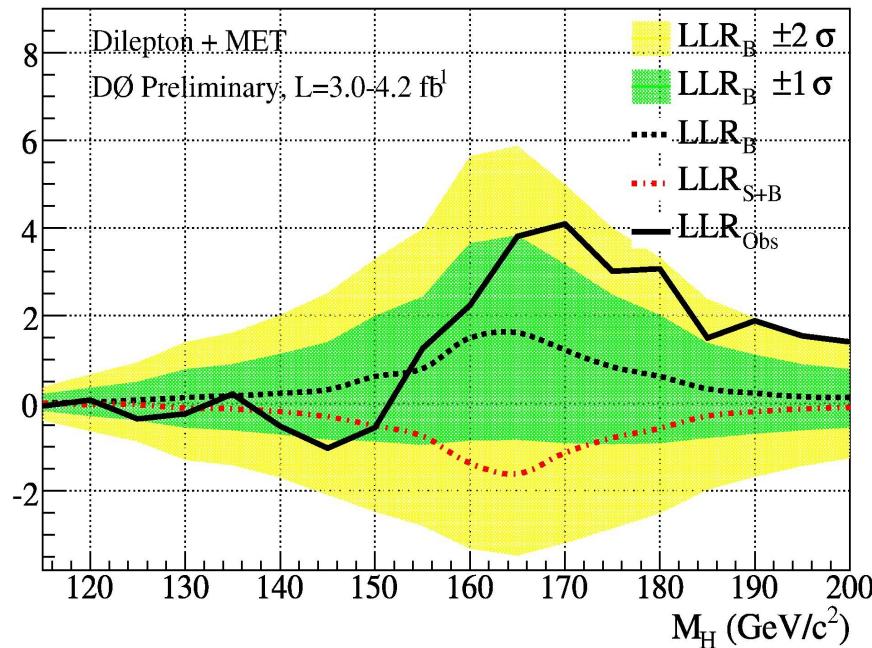
- $HWW, WW, ZZ, W\gamma, W+\text{jet}$

D0 models 2 modes:

- HWW and WW

Use a Likelihood Ratio

$$LR_m = \frac{P_m(\vec{x}_{obs})}{P_m(\vec{x}_{obs}) + \sum_i k_i P_i(\vec{x}_{obs})}$$



$M_H =$	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200
ee (exp.)	44	28	18	13	9.9	8.0	6.1	5.9	4.7	3.3	3.3	3.6	4.4	4.9	7.0	8.2	9.9	10
ee (obs.)	30	19	16	13	9.1	8.0	6.9	5.9	3.2	3.0	2.2	3.0	3.1	3.6	6.7	5.8	7.3	8.4
$e\mu$ (exp.)	40	23	19	11	11	8.5	7.7	4.3	3.5	2.6	2.3	2.7	3.2	3.8	5.1	6.4	7.6	8.4
$e\mu$ (obs.)	48	34	24	15	11	7.6	10	5.0	3.8	2.3	1.8	1.9	2.2	2.5	3.6	4.0	4.5	5.6
$\mu\mu$ (exp.)	94	36	23	16	16	11	10	8.2	7.6	6.4	5.7	5.9	7.7	9.2	12	14	16	19
$\mu\mu$ (obs.)	104	25	20	15	11	14	10	10	7.5	7.2	6.4	4.3	6.9	6.9	9.0	14	10	14
Run II (exp.)	23	13	9.6	6.3	5.6	4.7	4.0	2.9	2.4	1.8	1.7	2.0	2.4	2.9	4.0	4.8	5.8	6.7
Run II (obs.)	28	13	13	7.8	5.5	6.2	5.6	4.0	2.3	1.7	1.3	1.3	1.7	1.6	2.9	2.8	3.1	3.7

- **New x-sec: OS+SS**

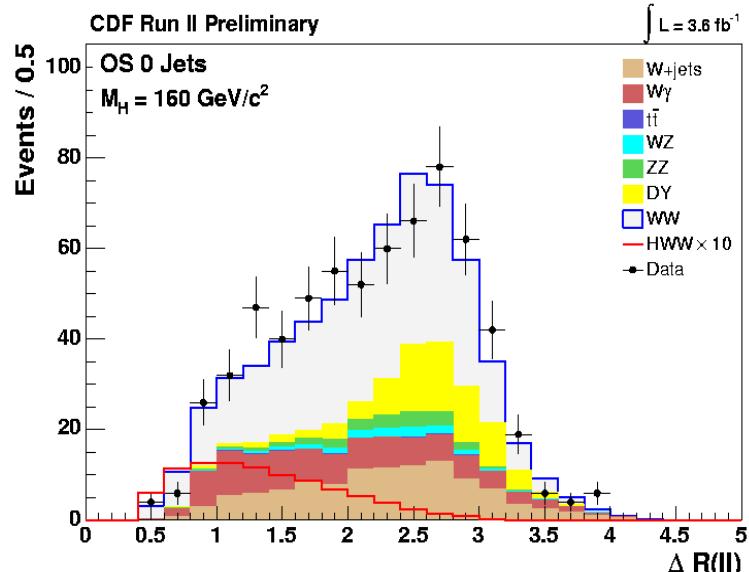
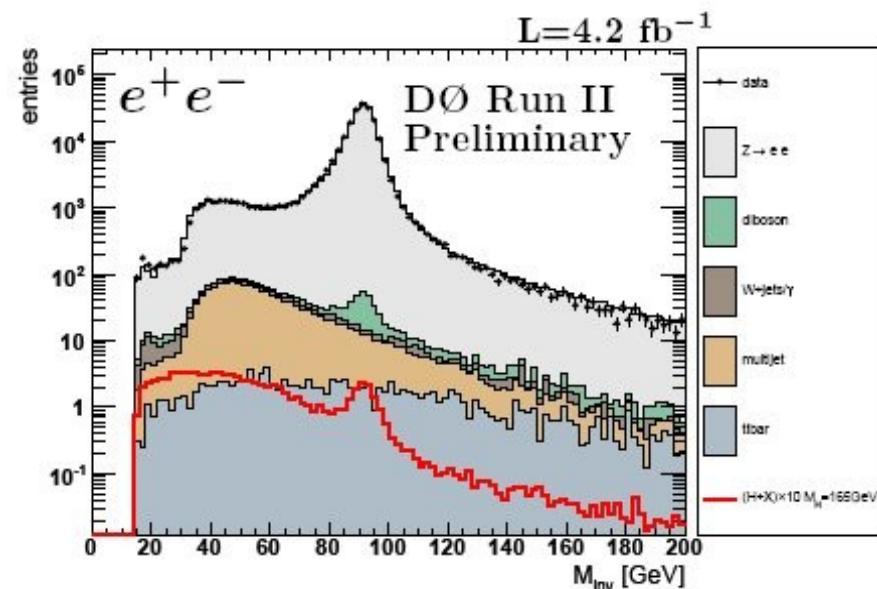
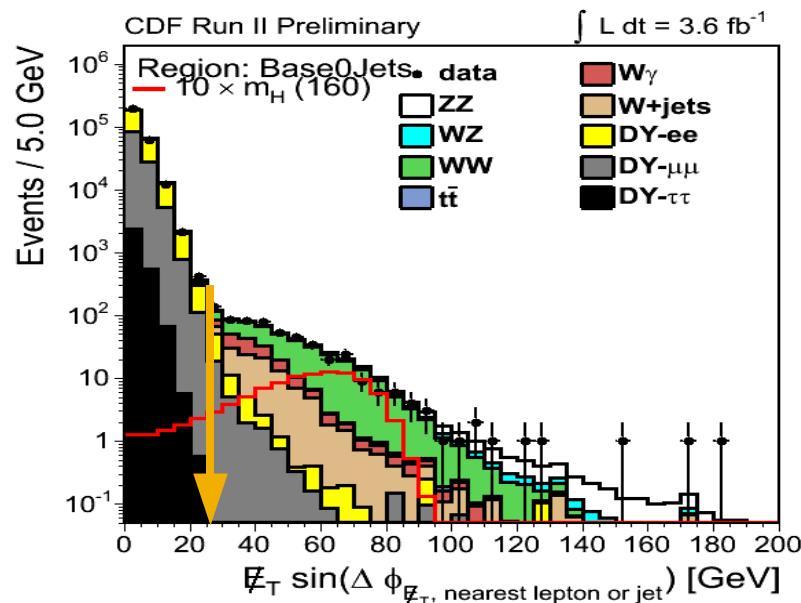
OS+SS	110	120	130	140	145	150	155	160	165	170	175	180	190	200
$-2\sigma/\sigma_{SM}$	15.48	5.31	2.60	1.69	1.47	1.23	1.04	0.79	0.77	0.88	1.08	1.21	1.92	2.52
$-1\sigma/\sigma_{SM}$	21.85	7.39	3.61	2.38	2.04	1.72	1.42	1.07	1.05	1.21	1.47	1.66	2.68	3.54
Median/σ_{SM}	31.48	10.62	5.26	3.40	2.94	2.46	2.02	1.52	1.50	1.73	2.10	2.40	3.84	5.11
$+1\sigma/\sigma_{SM}$	45.61	15.32	7.61	4.92	4.26	3.51	2.95	2.19	2.18	2.49	3.05	3.47	5.59	7.43
$+2\sigma/\sigma_{SM}$	63.79	21.54	10.71	6.82	6.01	5.02	4.14	3.12	3.00	3.49	4.24	4.88	7.78	10.66
Observed/σ_{SM}	51.05	12.22	6.06	3.52	3.14	2.39	1.99	1.37	1.33	1.81	2.02	2.23	3.56	6.24

- **ICHEP x-sec: OS+SS**

OS+SS	110	120	130	140	145	150	155	160	165	170	175	180	190	200
$-2\sigma/\sigma_{SM}$	16.26	5.45	2.62	1.71	1.44	1.23	1.00	0.75	0.74	0.85	1.00	1.17	1.82	2.39
$-1\sigma/\sigma_{SM}$	22.78	7.43	3.69	2.35	2.01	1.71	1.38	1.03	1.02	1.16	1.39	1.60	2.53	3.36
Median/σ_{SM}	32.40	10.79	5.31	3.36	2.92	2.44	1.97	1.47	1.45	1.66	2.00	2.31	3.65	4.89
$+1\sigma/\sigma_{SM}$	47.08	15.64	7.66	4.86	4.20	3.52	2.87	2.14	2.08	2.38	2.88	3.36	5.33	7.11
$+2\sigma/\sigma_{SM}$	66.21	21.71	10.63	6.91	5.89	4.96	4.03	2.96	2.95	3.36	4.09	4.76	7.49	10.08
Observed/σ_{SM}	52.20	12.58	5.88	3.56	3.11	2.31	1.91	1.37	1.29	1.67	2.01	2.03	3.59	5.94

- New pdf MSTW 2008
- Better treatment of b-quark
- 2-loop ewk corrections and NNLL x-sec already included

Improvements in Plots



- Lower Missing E_T
- Lower $m(H)$
- Lepton isolation
- Tri-lepton events
- Improve lepton acceptance/purity (and add new triggers)

Higgs Tevatron combination

- CDF and D0 combination: Bayesian method

$$\mathcal{L}(R) \times \pi(\vec{\theta}) = \prod_{i=1}^{N_C \cdot Nbins} \mu_i^{n_i} e^{-\mu_i} / n_i! \times \prod_{k=1}^{n_{NP}} e^{-\theta_k^2/2}$$

Flat Prior

$$\mu_i = R \times s_i(\vec{\theta}) + b_i(\vec{\theta}) = \text{expected events}$$

R = Signal in σ_{SM} units

n_i = “observed” events

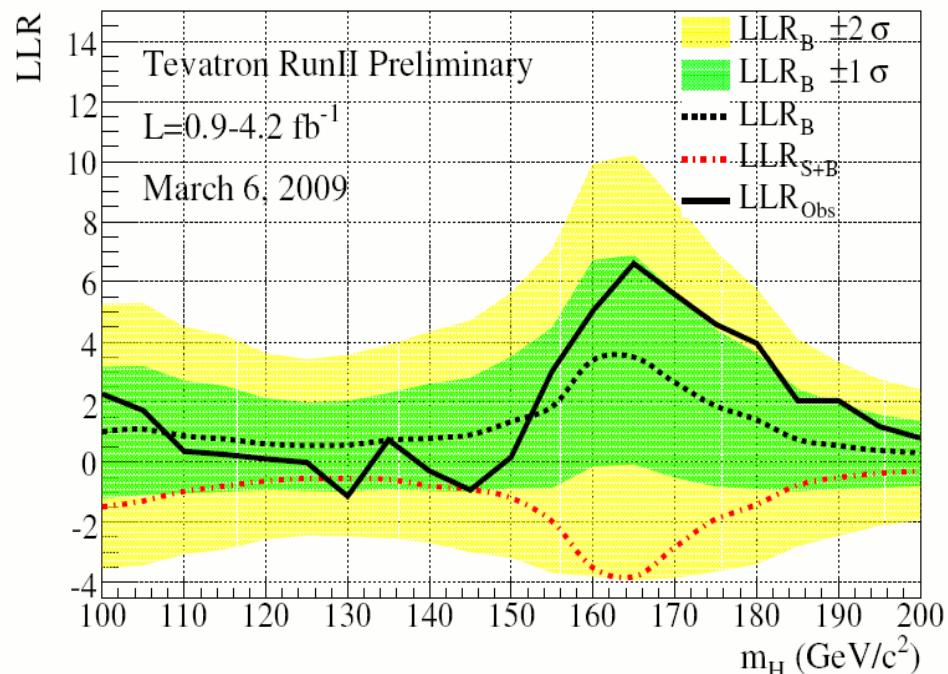
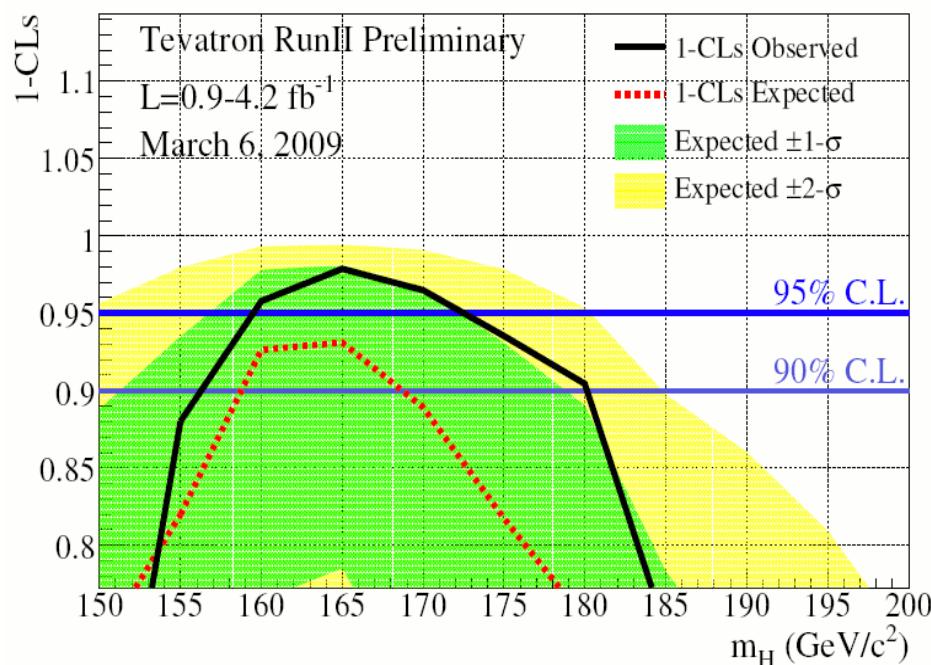
$\vec{\theta}$ = Nuisance parameters

Extract 95% CL limits on R integrating out nuisance parameters

- *It's not just a $\sqrt{2}$ factor: correlate systematics among experiments*

Tevatron 95% CL Limits

- Tevatron result with CL_s method



Tevatron 95% CL Limits

- Comparison CL_s and Bayesian

TABLE XVIII: Ratios of median expected and observed 95% CL limit to the SM cross section for the combined CDF and DØ analyses as a function of the Higgs boson mass in GeV/c^2 , obtained with the Bayesian and with the CL_s method.

Bayesian	100	105	110	115	120	125	130	135	140	145	150
Expected	2.0	2.0	2.2	2.4	2.7	2.9	2.9	2.7	2.5	2.4	1.8
Observed	1.9	1.8	2.4	2.5	2.8	3.0	3.5	2.4	2.7	2.8	1.9
CL_s	100	105	110	115	120	125	130	135	140	145	150
Expected	1.9	1.9	2.1	2.4	2.6	2.7	2.9	2.7	2.5	2.2	1.8
Observed	1.7	1.7	2.2	2.6	2.8	2.9	4.0	2.6	3.1	2.8	2.0

TABLE XIX: Ratios of median expected and observed 95% CL limit to the SM cross section for the combined CDF and DØ analyses as a function of the Higgs boson mass in GeV/c^2 , obtained with the Bayesian and with the CL_s method.

Bayesian	155	160	165	170	175	180	185	190	195	200
Expected	1.5	1.1	1.1	1.4	1.6	1.9	2.2	2.7	3.5	4.2
Observed	1.4	0.99	0.86	0.99	1.1	1.2	1.7	2.0	2.6	3.3
CL_s	155	160	165	170	175	180	185	190	195	200
Expected	1.5	1.1	1.1	1.3	1.6	1.8	2.5	3.0	3.5	3.9
Observed	1.3	0.95	0.81	0.92	1.1	1.3	1.9	2.0	2.8	3.3

Tevatron combination - $\log_{10} s/b$

